Geometric change of mitral valve leaflets and annulus after reconstructive surgery for ischemic mitral regurgitation: Real-time 3-dimensional echocardiographic study

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Ischemic mitral regurgitation (IMR) is a functional regurgitation characterized by structurally normal leaflets and subvalvular apparatus and is an important complication after myocardial infarction that is associated with excess mortality.[1] Reconstructive surgery, which restores a more normal alignment between the mitral annulus and displaced papillary muscles, might be beneficial in patients with IMR. However, little is known about the 3-dimensional (3-D) geometric changes of mitral leaflets and annulus after such reconstructive surgery for patients with IMR. We developed novel software, named Anatomical Image Creation System (AICS), which allows 3-D visualization and quantitative analysis of the mitral leaflets and annulus by using transthoracic real-time 3-D echocardiography (RT3DE).[2] We already demonstrated the apparent tenting of the mitral leaflets with flattened annulus in patients with IMR using this system.[3] In the present study we evaluated the 3-D geometric changes of the mitral leaflets and annulus in patients after reconstructive surgery for IMR using AICS.

Methods

We studied 3 patients who underwent mitral ring annuloplasty and concomitant left ventricular (LV) restorative surgery for severe IMR and severe LV systolic dysfunction caused by coronary artery disease. All the RT3DE examination was performed 1 week before and 3 weeks after the operation. LV systolic function and degree of mitral regurgitation (MR) were quantified by using 2-dimensional echocardiography. Using the transthoracic volumetric image by the RT3DE system with AICS, we created 3-D images of the mitral leaflets and annulus in midsystole for the 3-D quantitative measurements. The mitral leaflets' tenting volume was calculated as a volume enclosed between the 3-D annular plane and the mitral leaflets. Mitral annular size was measured by using those 3-D data sets as well (surface area, circumference, commissure-commissure diameter, and anterior-posterior diameter). Details of the 3-D image creation and measurements are described in our previous reports.[2,3] All 3 patients provided written informed consent to the study protocol, which was approved by the Committee for the Protection of Human Subjects in Research at Kawasaki Medical School.

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Results

All 3 patients had severe MR and severe LV systolic dysfunction before the operation. After the operation, MR disappeared and LV volume decreased in all 3 patients. The mitral leaflets' tenting volume and the size of the mitral annulus apparently reduced after the operation in all patients (Table 1). Preoperative 3-D images demonstrated the apparent tenting of the mitral leaflets, which showed mountain-shaped bulging with tethering into the left ventricle (Figure 1, left). After the operation, the mitral annulus visibly shrank, and the mitral leaflets' tenting volume was apparently smaller compared with that seen in preoperative images (Figure 1, right).

Discussion

In this study we demonstrated 3-D geometric changes of the mitral leaflets and annulus in patients undergoing reconstructive surgery for IMR using our novel AICS system with RT3DE.

Although annuloplasty is the current common surgical strategy for IMR,[4] MR often persists after annuloplasty. Recently, new surgical strategies, such as chordal cutting or papillary muscle repositioning with LV reshaping, have been expected to reduce persistent IMR after annuloplasty.[5] However, in the clinical setting it has been difficult to assess the geometric changes of the mitral leaflets and annulus after reconstructive surgery by using 2-dimensional echocardiography. Precise and comprehensive understanding of the 3-D geometric changes of the mitral leaflets and annulus should be needed for postoperative evaluation of valve repair. In this study, using novel AICS with RT3DE, we could visually and quantitatively compare the 3-D

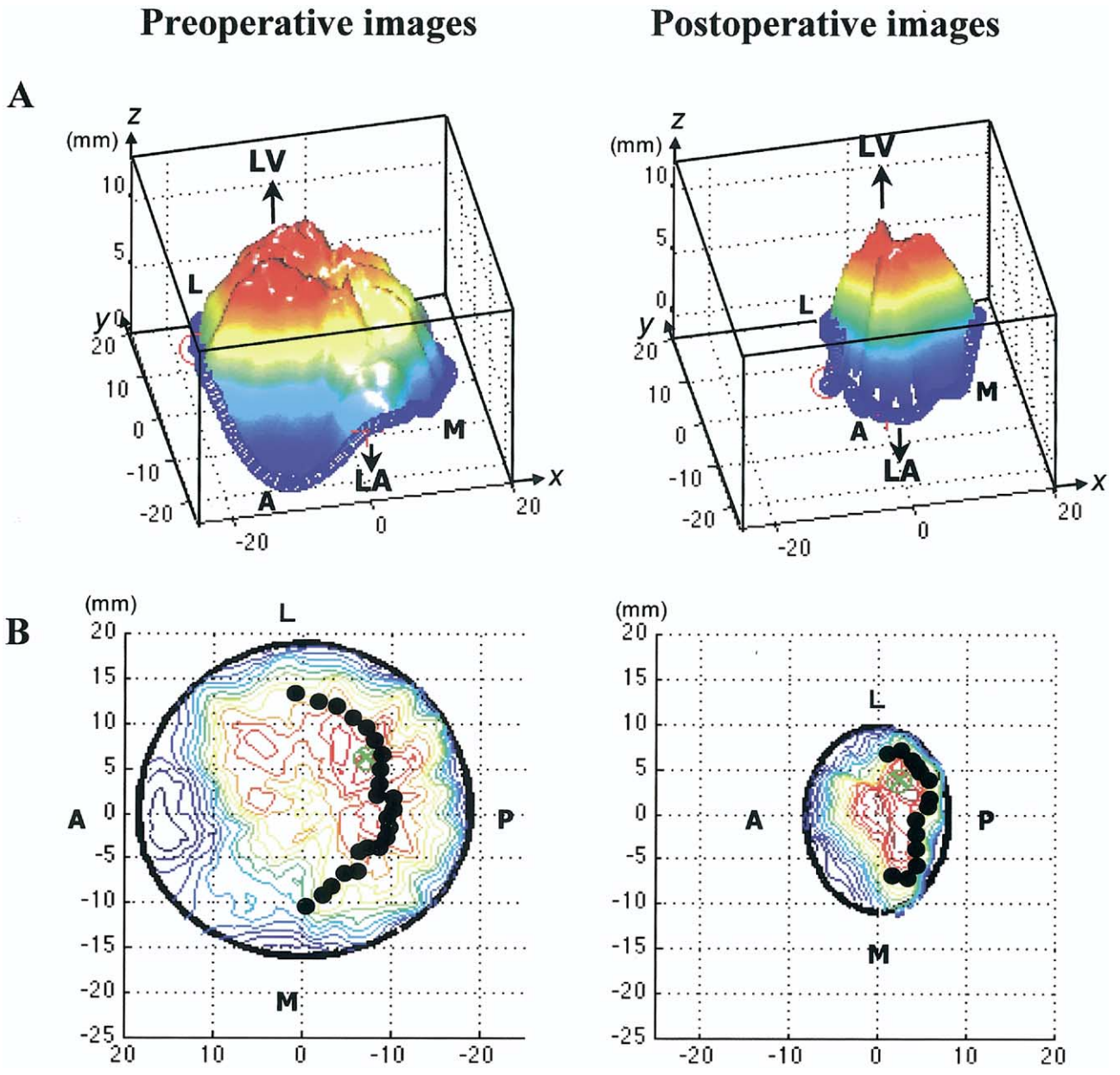

Figure 1. Three-dimensional images of the mitral leaflets and annulus in midsystole obtained from patient 2: *left*, preoperative images; *right*, postoperative images. A, Anatomic 3-dimensional images. The anatomic 3-dimensional images shows the actual configuration of the annulus and leaflets with surface colorations. The preoperative image *(left)* shows an apparent tenting of the mitral leaflets, which were tethered into the left ventricle, showing mountain-shaped leaflet bulging. In the postoperative image *(right)* the mitral annulus visibly shrank, and the mitral leaflets' tenting volume is apparently small. B, Actual 3-dimensional tenting images in the vertical view from the left ventricle. The mitral leaflets' configuration was represented in contour to appreciate the degree of tenting in the vertical from the left ventricle. The mitral annulus is dilated in the preoperative image *(left)*, and it is prominently small in the postoperative image *(right)*. *Black dots* indicate the coaptation line. *A*, Anterior; *P*, posterior; *L*, lateral; *M*, medial; *LV*, left ventricle; *LA*, left atrium.

TABLE 1. Clinical characteristics and 3-dimensional measurements of mitral annulus and leaflets

	Patient 1		Patient 2		Patient 3	
Age (y)	74		73		73	
Sex	Male		Male		Male	
Infarct territory	LAD		LAD, RCA		LAD	
Operation	Dor, MAP, PM repositioning		CABG, MAP, chordal cutting		SAVE, MAP, PM repositioning	
	Preop	**Postop**	**Preop**	**Postop**	**Preop**	**Postop**
LV						
EDV (mL)	258	160	134	107	108	80
ESV (mL)	217	131	75	49	68	58
EF (%)	15	18	44	54	37	28
MR						
Regurgitant volume (mL)	33	0	46	0	28	0
ROA (cm^2)	0.2	0	0.24	0	0.2	0
Mitral annulus						
Area (mm^2)	1165	509	1151	324	1488	422
Circumference (mm)	1210	800	1203	638	1367	728
c-c Diameter (mm)	40.6	25.7	34.9	20.7	40.1	22.0
a-p Diameter (mm)	37.4	22.4	37.4	16.2	36.7	19.8
Mitral leaflets						
Tenting volume (mm^3)	4219	2176	3872	1164	3541	320

LAD, Left anterior descending coronary artery; *RCA*, right coronary artery; *MAP*, mitral annuloplasty; *CABG*, coronary artery bypass grafting; *SAVE*, septal anterior ventricular exclusion; *PM*, papillary muscle; *Preop*, preoperative; *Postop*, postoperative; *LV*, left ventricle; *EDV*, end-diastolic volume; *ESV*, end-systolic volume; *EF*, ejection fraction; *MR*, mitral regurgitation; *ROA*, regurgitant orifice area; *c-c*, commissure-commissure; *a-p*, anterior-posterior.

geometry of the mitral leaflets and annulus in patients with IMR before and after the operation. Hence this technique would be helpful for the surgeon to evaluate the effect of reconstructive surgery on the 3-D geometry of the mitral leaflets and annulus in patients with IMR and to make a proper decision for surgical strategy for each individual in the clinical setting.

References

1. Grigioni F, Enriquez-Sarano M, Zehr KJ, Bailey KR, Tajik AJ. Ischemic mitral regurgitation: long-term outcome and prognostic implications with quantitative Doppler assessment. *Circulation.* 2001;103: 1759-64.
2. Yamaura Y, Watanabe N, Ogasawara Y, Yamamoto K, Kawamoto T, Toyota E, et al. Geometric demonstration and three-dimensional quantitative analysis of the mitral valve with real-time three-dimensional echocardiography: novel anatomical image creation system. *J Echocardiogr.* 2004;2:99-104.
3. Watanabe N, Ogasawara Y, Yamaura Y, Kawamoto T, Toyota E, Akasaka T, et al. Quantitation of mitral valve tenting in ischemic mitral regurgitation by transthoracic real-time three-dimensional echocardiography. *J Am Coll Cardiol.* 2005;45:763-9.
4. Gillinov AM, Cosgrove DM 3rd, Shiota T, Qin J, Tsujino H, Stewart WJ, et al. Cosgrove-Edwards Annuloplasty System: midterm results. *Ann Thorac Surg.* 2000;69:717-21.
5. Messas E, Pouzet B, Touchot B, Guerrero JL, Vlahakes GJ, Desnos M, et al. Efficacy of chordal cutting to relieve chronic persistent ischemic mitral regurgitation. *Circulation.* 2003;108(suppl):II111-5.